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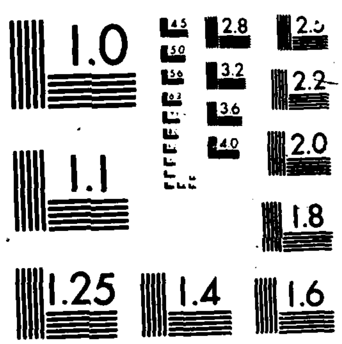
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FOREIGN TECHNOLOGY DIVISION

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by

Zhou Chaofu, Zhang Xuelin, et al.

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HUMAN TRANSLATION

FTD-ID(RS)T-0691-86 16 September 1986

MICROFICHE NR: FTD-86-C-002188

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By: Zhou Chaofu, Zhang Xuelin, et al.

English pages: 14

Source: Nanjing Daxue, Xuebao, pp. 395-402

Country of origin: China
Translated by: FLS, INC.
F33657-85-D-2079
Requester: FTD/WE
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DEZI [Expansion unknown] ANEMOMETER-BIVANE

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The working principles and characteristics of DEZI Anemometer-Bivane are introduced in this paper.

I. PREFACE

Presently, the several types of anemometer manufactured in our country can only measure horizontal wind velocity and wind direction change. As the research work in our country's near-surface meteorology and atmospheric pollution progress every dya, it demands more and better ground anemometers. In order to satisfy this need, we developed the DEZI Anemometer-Bivane. This instrument was approved by the certification conference which convened in July 1983 at Suzhou. The conference certified that said anemometer was a new wind velocity vector measuring instrument. It is capable of providing complete wind data at a point in space, i.e.total wind velocity and the directional and altitude angles of wind which occur simultaneously, thereby obtaining the three components of wind in the x,y,z direction. It is a better instrument for near-surface meteorological observation with excellent performance. Its design is reasonable, and it fills a blank in our country.

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The atmospheric diffusion coefficients σ_y and σ_z can be calculated from the data of the DEZI Anemometer-Bivane, and so do turbulence intensity and turbulence spectrum[1][2][3]. The data can be used in coordination with the data of equilibrium balloon observations to calculate the Lumley and Owens Correlational scale ratios[4]; and they can be combined with the data of temperature pulsation observations to calculated heat flow rate, etc.[5].

The appearance of DEZI Anemometer-Bivane is as shown in the pictures in Fig.1.

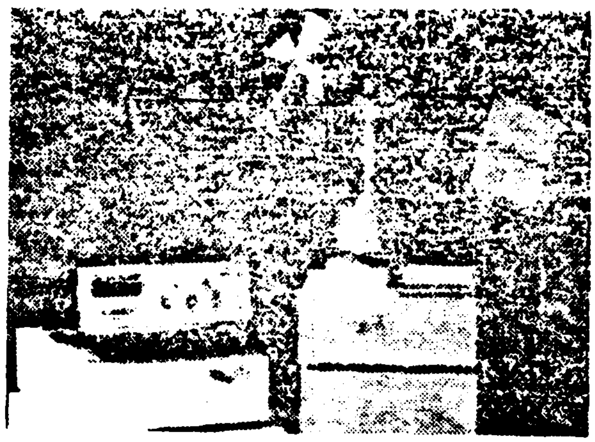

Fig.1. DEZI Anemometer-Bivane

When designing and manufacturing this instrument, its sensor must be not only as agile and sensitive as possible in order to obtain lower starting wind velocity and react to frequent changes of wind, but must also have adequate mechanical strength in order to be able to operate under rather large wind velocity; it must not only be able to duplicate measurements well at the same location and under the same external conditions, but must also have long-term stability at different locations and under different external conditions; it must not only be conveniently assembled and adjusted and equipped with advanced data recording and processing methods, but must also consider cost effectiveness, durability, and feasibility. In addition, it must also consider problems like waterproofing, dustproofing, corrosion resistance, and interference resistance, thereby creating more difficulties in the manufacturing of this instrument.

The instrument can be continuously operated under all outside conditions, except when there is liquid water present in the air. Its basic performance indexes are as follows:

Wind velocity measurement range: 0.2-25m/sec

Propeller starting wind velocity: 0.2m/sec

Wind direction indicator starting wind speed: 0.4m/sec

Error in wind velocity measurement: ±(0.2+0.03 x actual wind speed)

Horizontal wind direction measurement range: 0-360 degrees

Vertical wind direction measurement range: 0-±45 degrees

Error in horizontal wind direction measurement: ≤5 degrees

Error in vertical wind direction measurement: ≤5 degrees

The outputs are average total wind velocity, instantaneous total wind velocity, horizontal wind direction and vertical wind direction in binary parallel four-digit voltage codes and the corresponding analog signal of each digital signal.

II. PRINCIPLE

The DEZI Anemometer-Bivane is composed of the sensor and ground electronic devices.

The wind velocity sensor is a four-blade propeller, which is made of foaming polyvinylbenzene, mounted on the front of the sensor assembly using a microbearing with extremely small friction and an inner diameter of 3mm. It only weighs 11.5g, thus making the required starting wind velocity of the wind velocity sensor small and the response speed vast. The bivane tail wing is shaped like a cross and is also made of foaming polyvinylbenzene. The stand and connector of the sensor are made of a light aluminum alloy and stainless steel. The bivane can turn freely facing the wind in both horizontal and vertical directions simultaneously. Hence the propeller always turns facing the wind direction. The electrical signals are transmitted through the micromoment conducting ring. The sensor assembly is installed on the platform through the help of three bolts.

The circuitry principle diagram of the DEZI Anemometer-Bivane is as shown in Fig. 2.

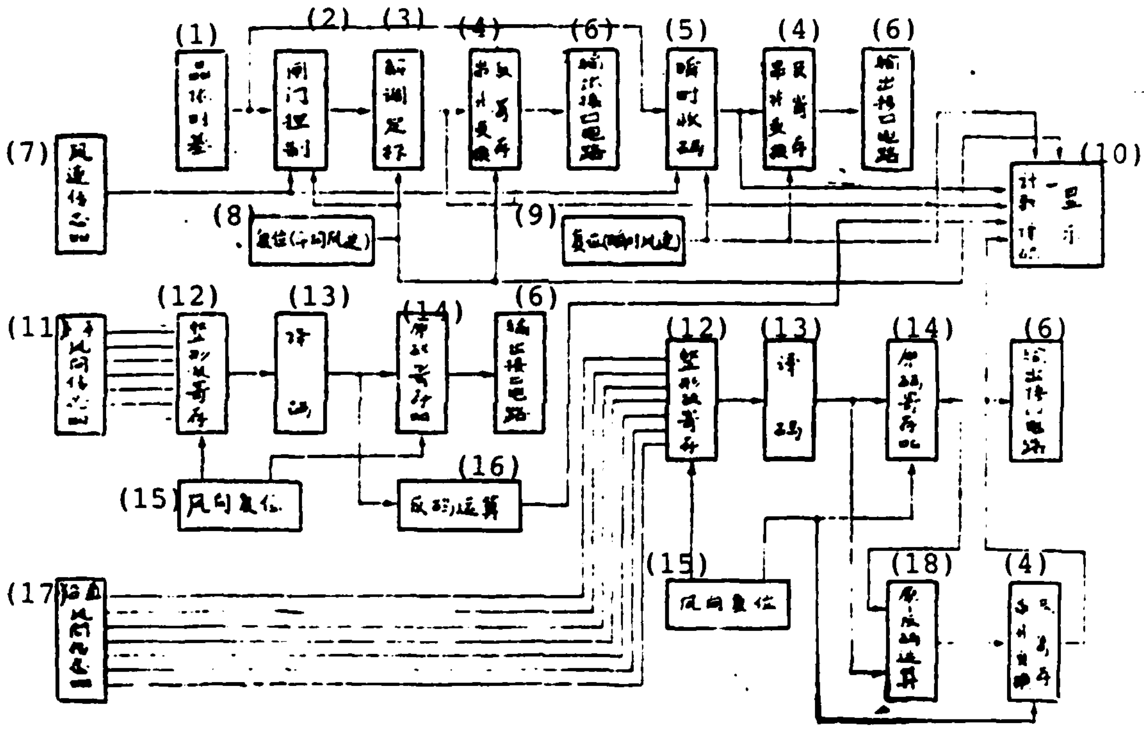

Fig. 2. Overall diagram of the DEZI Anemometer-Bivane
Key: (1) Crystal resonance time base; (2) Switch control; (3) Calibration adjustment; (4) Serial-parallel conversion and storage; (5) Instant code receiving; (6) Output outlet circuitry; (7) Wind velocity sensor; (8) Restore(average wind speed); (9) Restore (instantaneous wind speed); (10) Counter decoding display; (11) Horizontal wind direction sensor; (12) Transformation and storage; (13) Decoding; (14) Original coding storage device; (15) Wind direction restore; (16) Reverse coding operation; (17) Vertical wind direction sensor; (18) Original-reverse coding operation.

—The wind velocity transformer uses the opti-electrical transformation principle to convert the rpm of the propeller into corresponding number of pulses, and, through a cable, the pulse signals are transmitted to indoor electronic devices for processing. The wind direction transformer also uses the opti-electrical transformation principle, but the difference with wind velocity is that the bivane horizontal and vertical wind directions are converted into seven-digit cycling electric voltage codes, then, through the cable, the codes are transmitted to ground electronic devices for processing. The seven-digit circular dial is shown in Fig. 3, and the dial settings are as shown in Table 1[6]. The seven-digit cycling codes divide the angle of 0-360 degrees into 128 equal sections with each one representing 2.8125 degrees. The vertical wind direction uses only part of the seven-digit circular codes, i.e.32 equal sections.

Table 1

(e) 水平风向设置码							
(a) 设置循环码	(b) 显示值	(c) 理论值	(d) 误差	(a) 设置循环码	(b) 显示值	(c) 理论值	(d) 误差
0000001	1	1	0	0000001	1	1	0
0000011	2	2	0	0000011	2	2	0
0000010	3	3	0	0000010	3	3	0
0000110	4	4	0	0000110	4	4	0
0000100	7	7	0	0000100	7	7	0
0001100	8	8	0	0001100	8	8	0
0001000	15	15	0	0001000	15	15	0
0011000	16	16	0	0011000	16	16	0
0010000	31	31	0	(f) 备注	(g) 合格		
0110000	32	32	0				
0100000	63	63	0				
1100000	64	64	0				
(f) 备注	(g) 合格						

Key: (a) Cycling code setting; (b) Displayed value; (c) Theoretical value; (d) Error; (e) Horizontal wind direction setting; (f) Comments; (g) Acceptable

Fig. 3. Wind direction dial

The indoor electronic devices include the average wind velocity measurement circuits, instantaneous wind velocity measurement circuits, horizontal wind direction measurement circuits and vertical wind direction measurement circuits.

1. Average wind direction measurement circuits: They include

(1) Crystal resonance time base circuit: It can produce the corresponding control signals of 2 minute, 10 minute and 20 minute.

(2) Switch control circuit: Only when the switch is closed can the wind speed pulse signals be transmitted through the switch circuit.

(3) Calibration adjustment circuit: Its function is to convert the number of wind velocity pulse obtained in a sampling period to corresponding average wind velocity, and to conduct linear calibration with 4 wind velocity pulses corresponding to 0.1m/sec, thereby obtaining the average wind velocity values in m/sec.

(4) Serial-parallel code conversion circuit: It is used for parallel digital output and D/A conversion.

(5) Output outlet circuit: It is composed of digital output outlet circuit and analog conversion circuit. The former converts the internal digital signals to TTL voltage in order to connect computer and other external devices; the latter converts digital

to analog signals and also provides a low output resistance in order to connect to other analog recording devices.

(6) Restore control circuit: It ensures that the average wind velocity measurement circuit operates according to the required sequence.

(7) Display circuit: Through selection switch, average total wind speed, instantaneous wind velocity, horizontal and vertical wind directions can be displayed.

2. Instantaneous wind velocity measurement circuits

The instantaneous wind velocity measurement circuits are basically the same as the average wind velocity measurement circuits. The only difference is that the measurement cycle of instantaneous wind velocity is 2 second, not 2 minute, 10 minute and 20 minute.

3. Horizontal wind direction measurement circuits: They include

(1) Transformation and storage circuit: Through adjustment to electrical voltage of the transformation circuit the interference resistance character of the instrument can be improved. The circular codes output of the transformation circuit are sent to the storage device through the sampling circuit to ensure that the status of the storage device is only consistent with the circular codes within a sampling period and is not influenced by interference outside the sampling period.

(2) Cycling codes - binary codes decoding circuit: The cycling codes are decoded to binary codes in order to adapt to the operation of the instrument and the need for binary codes by computer outlet.

(3) Binary codes sampling - storage circuit: It sends the binary codes from the decoder through sampling circuit to the

storage device for storage. The parallel output codes from the storage device are connected to the digital output outlet circuit and the input terminal of the analog conversion circuit.

(4) Seven-digit serial reverse code addition circuit: The seven-digit serial reverse code adding device completes the serial-parallel conversion and control to allow the display device to conduct serial counting.

(5) Time control circuit: It keeps the various operations of the horizontal wind direction measurement circuit follow the required sequence.

(6) Output outlet circuit: It also includes digital output outlet circuit and analog conversion circuit. Its function and circuit form are basically the same as the wind velocity measurement circuit. The only difference is that it adopts a seven-digit instead of nine-digit D/A converter.

4. Vertical wind direction measurement circuits

The vertical wind direction measurement circuits and the horizontal wind direction measurement circuits are basically the same. Since the range of vertical wind direction measurement is 0-±45 degrees, the output digital signals must contain a sign position and the output analog signals must contain positive and negative polarity. Hence it is different from horizontal wind direction measurement circuits in the following areas:

(1) The digital output circuit is added with a sign position.

(2) The original seven-digit reverse codes adding device can display a corresponding positive or negative wind direction sign.

(3) The analog conversion circuit makes the output analog signals contain positive and negative polarity corresponding to the angular values of wind direction.

IV. CHARACTERISTICS EXPERIMENTS

Experiments were conducted for the characteristics of the DEZI Anemometer-Bivane:

(1) Propeller starting wind velocity: The results are as shown in Table 2.

Table 2.

(1) 日 期	(2) 测 试 设 备	(3) 起 动 风 速
(4) 82年10月16日	(5) 国家气象局风洞室	(6) 0.16米/秒

Key: (1) Date; (2) Testing facility; (3) Starting wind velocity; (4) October 16, 1982; (5) Wind Tunnel room at the National Bureau of Meteorology; (6) m/sec.

(2) Wind direction starting wind speed: The results are as shown in Table 3.

Table 3

(1) 日 期	(2) 测 试 设 备	(3) 风标初始位置	(4) 起 动 风 速
82年10月16日 (5)	国家气象局风洞室 (6)	20°	0.56米/秒 (7)
		170°	0.28米/秒 (7)
		190°	0.36米/秒 (7)
		340°	0.23米/秒 (7)

Key: (1) Date; (2) Testing facility; (3) Initial wind direction setting; (4) Starting wind direction; (5) October 16, 1982; (6) Wind Tunnel Room at the National Bureau of Meteorology; (7) m/sec.

(3) Maximum wind velocity: The instrument operated continuously for 3 minutes under a wind velocity of 30.44m/sec at the Wind Tunnel Room of the National Bureau of Meteorology. Experiments showed that the instrument operated completely normally under said wind velocity. Based on this, the maximum measurable wind velocity was set as 25m/sec.

(4) Wind velocity verification curves: The experimental results of wind tunnel wind velocity as related to the instrument displayed wind velocity are as shown in Table 4, and the verification curve is as shown in Fig. 4.

Table 4

(1)日 期	(2)测试设备	(3)风洞风速	(4)指示风速
82年10月16日	国家气象局风洞室	5.25米/秒	5.0米/秒 (7)
(5)	(6)	9.19米/秒	8.9米/秒(7)
		14.33米/秒	13.9米/秒(7)
		18.26米/秒	17.7米/秒(7)
		23.71米/秒	23.1米/秒(7)
		29.68米/秒	28.9米/秒(7)
		30.44米/秒	29.8米/秒(7)

Key: (1) Date; (2) Testing facility; (3) Wind tunnel wind velocity; (4) Indicated wind velocity; (5) October 16, 1982; (6) Wind Tunnel Room of the National Bureau of Meteorology; (7) m/sec.

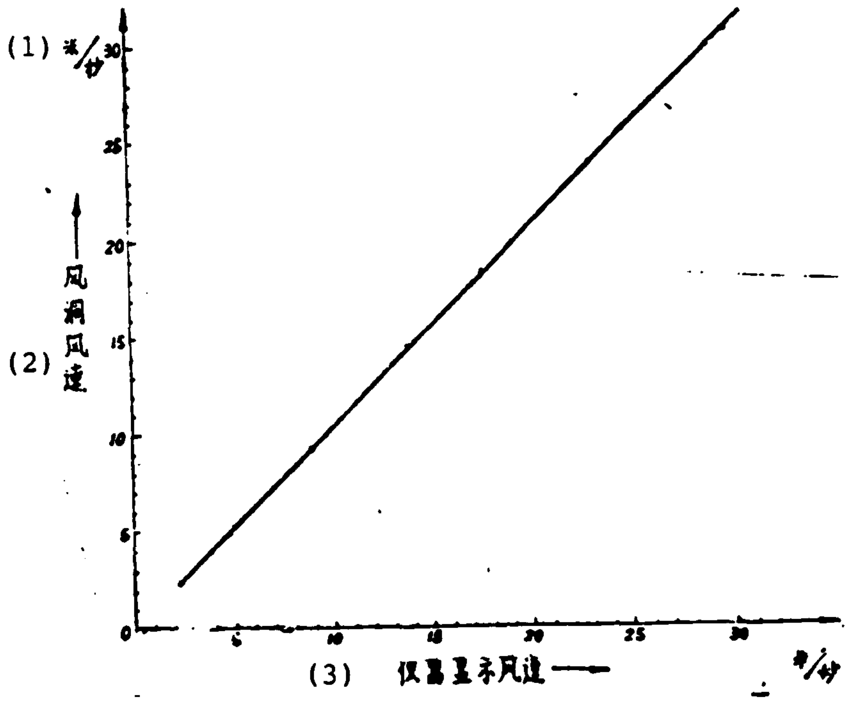

Fig.4 Wind speed verification curve
Key: (1) m/sec; (2) Wind tunnel wind speed;
(3) Instrument displayed wind velocity.

(5) Response of propeller to different incident angles: The response of ideally shaped propeller to incoming flow with different incident angles should follow the cosine rule, that is

$$V_\theta = V\cos\theta$$

where V_θ is the component of the wind velocity in the propeller's axial direction. θ is the angle between the propeller axis and the incoming flow in the wind tunnel, i.e. the incident angle. V is the wind speed.

The experiment results of response to incident angles are as shown in Table 5.

Table 5

θ	$\cos\theta$	(a) V (米/秒)	V_θ (米/秒) (a)	实测值(米秒/) (b)	误差(米/秒) (c)
2.8°	0.998	3.7	3.69	3.7	+0.01
11.25°	0.980	3.7	3.63	3.6	-0.03
22.5°	0.924	3.7	3.42	3.4	-0.02
36.5°	0.804	3.7	2.97	2.85	-0.12
50.°	0.643	3.7	2.38	2.25	-0.13
64.7°	0.427	3.7	1.58	1.4	-0.18
90°	0	3.7	0	0	0

Key: (a) m/sec; (b) Measured values (m/sec); (c) Errors (m/sec).

(6) Distance constant of the anemometer

(An) Anemometer of rotational type is a non-oscillating system. Its response to a staged input is to increase monotomously toward a new equilibrium value. This system is completely determined by a single time constant T or a distance constant L. T is the time required for the change to reach the final equilibrium value of $1-\frac{1}{e}$[7], and $L=V_0T$, where V_0 is the equilibrium wind velocity. The results of the experiment indicate that the distance constant of the DEZI type anemometer is 1.0m.

(7) Damping ratio and nondamping inherent wave length of the wind direction indicator: The dynamic effects of the wind direction indicator can be expressed by damping ratio and nondamping inherent wave length. The quantities of these charac-

teristics can be calculated from the oscillation curves[8]. When overoscillation is small, the calculation formula of the damping ratio ξ can be expressed as:

$$\xi = \left[\frac{(\ln \frac{h}{H})^2}{\pi^2 + (\ln \frac{h}{H})^2} \right]^{\frac{1}{2}}$$

where $\frac{h}{H}$ is the overoscillation ratio of the wind direction indicator. The calculation formula of nondamping inherent wave length is:

$$\lambda_0 \quad \lambda_d (1 - \xi^2)^{\frac{1}{2}}$$

or

$$\lambda_d = D(6.0 - 2.4\xi)$$

where λ_d is the damping inherent wave length of the wind direction indicator and D is the lagging distance of the wind direction indicator. They can all be obtained from the oscillation curve of the wind direction indicator.

The damping ratio of the wind direction indicator of the DEZI Anemometer-Bivane obtained from the results of the experiment is 0.39 and the nondamping inherent wave length 6.9m. These indexes are capable of satisfying the needs of research work in turbulent flow and diffusion[7].

In addition to the above characteristics experiments, we also conducted experiments on the instrument's ability to duplicate measurements, the sensor's interchangeability and other effects, such as temperature, humidity, etc. The results indicate that the characteristics of the instrument meet the related technical requirements or conditions.

IV. CONCLUSIONS

Although the design of the DEZI Anemometer-Bivane has been finalized, there are still areas that need further improvement.

For example, the starting wind velocity of the wind direction indicator still needs to be lowered, and certain mechanical structures need improvement, etc. We plan to further develop areas in the instrument's intelligence and systems hereafter. The developmental processes of said instrument indicate that combining the develpment of new products with the triple-combination of scientific research units, factories and schools is a good cooperative method.

The names which appeared in this paper as authors were only primary members of the research staff for this instument. In fact, we received great support and assistance from many comrades and units during the developmental processes. We hereby express our special thanks for their labor and assistance.

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